UTILITY SCALE

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Breakout Session

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Targets and design considerations

- Distribution voltage – 13kV+ class (medium voltage)
  - Anything lower doesn't help utility in integration
- In 500kW-1MW class, without DC boost situation limited by wiring losses
- Another approach: much higher levels and modularity in DC/DC stage
  - Design system so it is expandable
- Factors to decide the design point
  - Design right now is on the order of 1MW
  - Smaller maintenance drives this. Put it all in one spot.

Targets and design considerations (cont'd)

- Inverter is only a portion of what goes in building. Overhead you want to minimize. To enable bigger inverter PCS, need higher V.
- High power inverters exist. The problem is the system.
  - How to go in modular structure and integrate these voltages where you can use a bigger inverter?
  - DC/DC booster phase is an option

Components required to dramatically increase power density while reducing the cost of the inverter

- High freq switches
  - Proven high voltage, high frequency switches semiconductor switches
    - SiC - have square SOA (safe operating area)
  - Make SiC and GaN available in market – demonstrate reliability
  - Simple bridge circuit with minimum recovery charge

- High freq, high flux magnetics
  - Low-loss high-flux for frequency range
  - Winding designs
  - Note: If switches limit frequency, then magnetics will be bound there

- Packaging
  - Insulation
  - Cooling

Proposed methodologies to evaluate first cost of power electronics

- No consensus reached. Thoughts:
  - First, have to build it before you model cost
  - Volume of manufacturing has to be part of your cost modeling
  - Partnership across the supply chain will allow team to discuss cost targets, or having customer on your team
  - "Should cost" modeling – a la silicon
  - Must look at it from system level
    - Devices
    - Topologies
  - Has to meet UL – but would require UL tester as a partner?
  - First cost metric is the toughest because of all varied topologies

Utility-scale PV - target operating voltages and power

1. For utility-scale PV, what are target operating voltages and power?

- Distribution voltage – 13kV+ class (medium voltage)
  - Anything lower doesn't help utility in integration
- In 500kW-1MW class, without DC boost situation limited by wiring losses
- Another approach: much higher levels and modularity in DC/DC stage
  - Design system so it is expandable
- Factors to decide the design point
  - Design right now is on the order of 1MW
  - Smaller maintenance drives this. Put it all in one spot.

Utility-scale PV - Effect of inverter properties on installation cost

2. What properties of the inverter contribute to the overall installation cost for utility-scale PV systems? How much?

- Weight and footprint, yes
- Input DC V is trickier
  - Drives O&M. Higher voltage means longer wiring… less inverters.
  - Going higher would be great, but need materials at cost
  - We do 600V now b/c it's a nice sweet spot
  - 1000V or higher needs to be behind fence
- Output Voltage. 13kV?

3. What is the appropriate design increment for modular utility-scale inverters? 500kW?

- In 500kW-1MW class, without DC boost situation limited by wiring losses
- Another approach which is much higher levels and modularity is in dc/dc stage
  - Design system so it is expandable
- Factors to decide the design point
  - Design right now is on the order of 1MW
  - Smaller maintenance drives this. Put it all in one spot
- Inverter is only a portion of what goes in building. Overhead you want to minimize. To enable bigger inverter VCS, need higher V
- High power inverters are there. The problem is the system
  - How to go in modular structure and integrate these voltages where you can use a bigger inverter?
  - DC/DC booster phase is what it keeps coming back to

State-of-the-art power density for a PV inverter for 500kW-60MW systems

4. What is the state-of-the-art power density for a PV inverter for 500kW-60MW systems?

- Cabinet is 8’x20’x4’ for 1MW
- Systems designed for someone to walk through, so this isn’t for power electronics itself

Proposed circuit architecture approaches

5. Consider <u>circuit architectures</u> that can drive to dramatic reductions in weight, size, and cost.

- Talking about system architectures is just as important as circuit architectures
- Dramatically smaller
  - Inverter itself smaller
  - Low frequency transformer goes away (probably 10%)
- Dc/Dc isolated transformer structure
  - High frequency reduces size weight and cost
- Size of PCS is dominated by servicability
- Opportunity not in making PCS smaller, but in Pcs 10X more powerful

Switching frequency employed in today's state-of-the-art inverters for utility-scale PV

6. What is the switching frequency employed in today's state-of-the-art inverters for utility-scale PV? 5kHz?

- 3, 5, 8, 15kHz has been seen
- 15 in testing phase
- No reason not to go higher for 480V system
- Depends on whether you have booster stage or not
- As long as doesn't generate harmonics – but may be easier to filter at higher frequency
- Advantages of going higher:
  - reducing size of filter components
  - Efficiency
  - No need to store energy on board – do not need electrolytic capacitor

Components required to dramatically increase power density while reducing the cost of the inverter

7. Consider the components required to dramatically increase power density while reducing the cost of the inverter.

- Will take innovations in all areas
  - High freq switches
    - Proven high voltage, high frequency switches semicondutor switches
      - SiC - have square SOA (safe operating area) – breaking past the limited rating/use of the device of other materials
    - Make SiC and GaN available in market – demonstrate reliability
    - Simple bridge circuit with minimum recovery charge
  - High freq, high flux magnetics
    - Low loss high flux for freq range
    - If switches limit frequency, then magnetics will be bound there
    - Winding designs
  - Packaging
    - Insulation
    - Cooling

Issues related to isolation and grounding

8. Address issues related to isolation and grounding?

- When they put a lot of DC lines in one area, lighting has been induced. Higher V tends to induce more lightning

Proposed methodologies to evaluate first cost of power electronics

9. What methodology can be used to evaluate first cost of the power electronics? How can progress against cost metrics be evaluated?

- First have to build it before you model cost
- Volume of manufacturing has to be part of your cost modeling
- Partnership across the supply chain will allow team to discuss cost targets, or having customer on your team.
- “Should cost” modeling – a la silicon
- Must look at it from system level
  - Devices
  - Topologies
- Has to meet UL – but would require UL tester as a partner?
- First cost metric is the toughest because of all varied topologies